Examining courses of sleep quality and sleepiness in full 2 weeks on/2 weeks off offshore day shift rotations

Riethmeister, V; Bültmann, U; De Boer, M R; Gordijn, M; Brouwer, S

Published in:
Chronobiology International

DOI:
10.1080/07420528.2018.1466794

Publication date:
2018

Chronobiology International

The Journal of Biological and Medical Rhythm Research

ISSN: 0742-0528 (Print) 1525-6073 (Online) Journal homepage: https://www.tandfonline.com/loi/icbi20

Examining courses of sleep quality and sleepiness in full 2 weeks on/2 weeks off offshore day shift rotations

V. Riethmeister, U. Bültmann, M.R. De Boer, M. Gordijn & S. Brouwer

CHRONOBIOLOGY INTERNATIONAL
2018, VOL. 35, NO. 6, 759–772
https://doi.org/10.1080/07420528.2018.1466794

Examining courses of sleep quality and sleepiness in full 2 weeks on/2 weeks off offshore day shift rotations

V. Riethmeister[a], U. Bültmann[a], M.R. De Boer[b], M. Gordijn[c], and S. Brouwer[a]

[a]Department of Health Sciences, Community and Occupational Medicine, University Medical Center Groningen, University of Groningen, Groningen, The Netherlands; [b]Department of Health Sciences and the EMGO+ Institute for Health and Care Research, Faculty of Earth and Life Sciences, VU University Amsterdam, Amsterdam, The Netherlands; [c]Chrono@Work B.V. Groningen, The Netherlands, and Chronobiology Unit, Groningen Institute for Evolutionary Life Sciences, University of Groningen, Groningen, The Netherlands

ABSTRACT

To better understand sleep quality and sleepiness problems offshore, we examined courses of sleep quality and sleepiness in full 2-weeks on/2-weeks off offshore day shift rotations by comparing pre-offshore (1 week), offshore (2 weeks) and post-offshore (1 week) work periods. A longitudinal observational study was conducted among N=42 offshore workers. Sleep quality was measured subjectively with two daily questions and objectively with actigraphy, measuring: time in bed (TIB), total sleep time (TST), sleep latency (SL) and sleep efficiency percentage (SE%). Sleepiness was measured twice a day (morning and evening) with the Karolinska Sleepiness Scale. Changes in sleep and sleepiness parameters during the pre/post and offshore work periods were investigated using (generalized) linear mixed models. In the pre-offshore work period, courses of SE% significantly decreased (p=.038). During offshore work periods, the courses of evening sleepiness scores significantly increased (p<.001) and significantly decreased during post-offshore work periods (p=.004). During offshore work periods, TIB (p<.001) and TST (p<.001) were significantly shorter, SE% was significantly higher (p=.002), perceived sleep quality was significantly lower (p<.001) and level of rest after wake was significantly worse (p<.001) than during the pre- and post-offshore work periods. Morning sleepiness was significantly higher during offshore work periods (p=.015) and evening sleepiness was significantly higher in the post-offshore work period (p=.005) compared to the other periods. No significant changes in SL were observed. Courses of sleep quality and sleepiness parameters significantly changed during full 2-weeks on/2-weeks off offshore day shift rotation periods. These changes should be considered in offshore fatigue risk management programmes.

ARTICLE HISTORY
Received 21 September 2017
Revised 16 February 2018
Accepted 27 March 2018

KEYWORDS
Actigraphy; Fatigue; Fatigue Risk management; Occupational Health; Occupational Safety

Introduction

Poor sleep quality (Menezes et al. 2004; Parkes 2016; Parkes 2015; Parkes 2002; Parkes 1994; Riethmeister et al. 2016) and high sleepiness levels (Parkes 1993; Riethmeister et al. 2016; Waage et al. 2012) are common problems among offshore workers in the oil and gas industry. Offshore work and living conditions, such as remote shift work, long periods of consecutive work days (e.g. 1–4 weeks), extended work hours (e.g. 12-h shifts) and sleeping on site (e.g. noise disturbances), are likely to predispose offshore workers to experience higher levels of sleep- and sleepiness-related problems, which can ultimately result in health and safety hazards (Arlinghaus et al. 2012; Folkard and Tucker 2003; Parkes 2012; Uehli et al. 2014). In the past, some of the major offshore oil and gas industry disasters (e.g. the Macondo disaster close to the Gulf of Mexico in 2010 or the Piper Alpha disaster close to the coast of Aberdeen in 1988) have been linked to fatigue-related human errors (Gordon 1998; U.S. Chemical Safety and Hazard Investigation Board 2016).

Disrupted sleep can arise from a multitude of factors, such as adverse external sleep hygiene factors (e.g. noise, temperature, quality of mattresses) and interpersonal factors such as psychological (e.g. stress, rumination, anxiety levels) and physical conditions (e.g. sleeping disorders, general health status) (Jepsen et al. 2015). Sleep research in work environments has shown that working extended hours increases the risk for

CONTACT Vanessa Riethmeister v.riethmeister@umcg.nl Department of Health Sciences, Community and Occupational Medicine, University Medical Center Groningen, University of Groningen, Antonius Deusinglaan 1, 9713 AV, Groningen, The Netherlands

Supplemental data for this article can be accessed on the publisher's website.

sleep disturbances (Muller et al. 2008; Wadsworth et al. 2006), coronary heart disease and recovery times (Jansen et al. 2003; Kivimaeki et al. 2011). These adverse (health) outcomes are of occupational health, safety and economic concern. Sleepiness is directly linked to sleep quality and impaired functioning. Here, sleepiness is defined as “the increase in the propensity for sleep brought on by reduction or fragmentation of sleep, the nadir of the circadian rhythm in alertness or factors that affect the central nervous system” (p.1099) (Mullins et al. 2014). High sleepiness levels have been associated with decreased attention and accident involvements (Åkerstedt et al. 2011). In work settings, sleepiness has been shown to accumulate over extended work hours in short work periods (Kecklund et al. 2001) and to increase during the duration of 2 week offshore shifts (Waage et al. 2012). Both the long 12-h offshore work days and the extended duration of offshore shift rotations may result in even higher sleepiness levels at work and may increase the risk of adverse health and safety outcomes.

To date, in-depth knowledge on the effects of offshore (day) shifts on sleep quality and sleepiness across full offshore shift rotations is lacking. Offshore shifts and rotations differ in duration, ranging from 1-week-on/1-week-off, to 4-weeks-on/4-weeks-off, and various in-between scenarios. In the Dutch Continental Shelf, 2-weeks-on/2-weeks-off (2on/ 2off) 12-h offshore day shift rotations are the most commonly operated rotation schedule. Thus far, most offshore sleep (quality) and sleepiness research has focused on differences between shift schedules (e.g. fixed night shift and swing shift) and has predominantly focused on offshore work periods. Here, a fixed shift refers to either 2 weeks of day shift or 2 weeks of night shift. A swing shift refers to 1 week of day shift followed by 1 week of night shift or the reverse. To the best of our knowledge, only a few offshore studies from predominantly the same research group have investigated sleep quality and sleepiness parameters across full offshore shift rotations, including pre- and post-offshore work periods (Harris et al. 2010; Saksvik et al. 2011; Waage et al. 2012; Waage et al. 2013), and only a few more have investigated sleep quality and sleepiness parameters in solely post-offshore work periods (Bjorvatn et al. 1999; Gibbs et al. 2002; Gibbs et al. 2007; Merkus et al. 2015a; Merkus et al. 2015b; Parkes 2016; Thorne et al. 2010). Overall, differences and spill-over effects between pre-/ post- and offshore work periods were identified highlighting the importance of considering both pre- and post-offshore work periods in offshore health and fatigue risk management programmes (Ferguson et al. 2010; Merkus et al. 2015b; Saksvik et al. 2011; Thorne et al. 2010; Waage et al. 2012).

Offshore workers reported poorer sleep quality at the end compared to before offshore work periods (Waage et al. 2013). Additionally, some studies have indicated a psycho-physiological recovery period after 2 weeks of offshore work among both day and night shift workers (Merkus et al. 2015b; Saksvik et al. 2011; Thorne et al. 2010; Waage et al. 2012). In general, if recovery processes of psychophysiological systems are impeded and systems cannot return to baseline levels of activation for a prolonged period of time, this can lead to impaired health status (Geurts and Sonnentag 2006). The main limitation of these studies is that they used relatively few measurement time points for sleep quality and sleepiness parameters. Moreover, all studies, except one (Saksvik et al. 2011), used subjective, self-reported sleep diary and questionnaires data only. To adequately investigate sleep quality parameters, it has been suggested to use both objective and subjective, self-reported measures simultaneously to improve the accuracy of the results (Gehrman et al. 2002; Mullins et al. 2014).

In the present study, we examined the courses of sleep quality and sleepiness in full 2on/2off offshore day shift rotations using objective and subjective, self-reported, measures. Pre-offshore (1 week), offshore (2 weeks) and post-offshore (1 week) work periods were compared. We hypothesized that: (1) courses of sleep quality parameters will decrease and courses of sleepiness parameters will increase during the offshore work periods and revert during the post-offshore work periods; (2) sleep quality will be poorest during offshore work periods, with short sleep durations (time in bed), low sleep efficiency percentage scores and short sleep onset times (sleep latencies); (3) sleepiness levels will be highest during offshore work periods; and (4) poor sleep quality and sleepiness scores will remain high in the first week of the post-offshore work period.

Materials and methods

Study design and population

A longitudinal observational study was conducted among $N = 42$ offshore day shift workers, working on four different offshore platforms located in the Dutch Central North Sea between February and June 2015. The total study period was 4 weeks (one full offshore shift rotation), starting with 1 week of leave (pre-offshore), followed by 2 weeks of offshore work and followed by one more week of leave (post-offshore). All offshore shifts started at 07:00 h and ended at 19:00 h. No overtime work was requested nor recorded in the offshore management system. Permanent staff and contractors were invited to take part in the study by means of invitation emails and promotional material (flyers, posters, banners), which were distributed on the four participating offshore platforms. On the first study day, all offshore workers received an electronic baseline questionnaire on demographic, work and health variables. For the entire study period, bi-daily electronic sleep diaries were sent to the offshore workers at 06:00 h and at 18:00 h. Compliance was monitored remotely and reminders were sent to the offshore workers if needed. When offshore workers did not complete their sleep diaries by noon/bedtime, scores were classified as missing. On average, offshore workers sleeping accommodations consisted of a two-person shared cabin with ensuite bathroom. On each platform, several sample cabins were assessed for sleep hygiene factors such as noise, temperature and humidity levels. All sampled cabins scored within recommended ranges (Kim and Van Den Berg 2010; National Sleep Foundation 2018).

Offshore workers were excluded from the study if they performed any form of night shift during the study period (Figure 1). Study participation was voluntarily. Informed consent was obtained from all participants. The experimental protocol was conform to the international ethical standards (Portaluppi et al. 2010) and ethical approval for the study was granted from the Medical Ethics Committee of the University Medical Center Groningen, The Netherlands (reference number: M14.165646).

Measurements

Sleep parameters

Actigraphy was used to measure sleep quality parameters objectively. The following sleep quality parameters were measured: time in bed (TIB), the total elapsed time between the 'lights out' and 'got up' times; total sleep time (TST), the total time spent in sleep according to the epoch-by-epoch wake/sleep categorization; sleep efficiency percentage (SE%), the actual sleep time expressed as a percentage of time in bed; and sleep latency (SL), the time taken to transition from wakefulness to sleep. A light-weight, waterproof, wrist-worn actigraph (MotionWatch 8®, Camntech, Papworth Everard, UK) was used to measure data continuously. The MotionWatch8® has been shown to be a valid and reliable measure for sleep parameters, using tri-axial sensors data (Elbaz et al. 2012). Generated data consisted of 1-min epochs. The

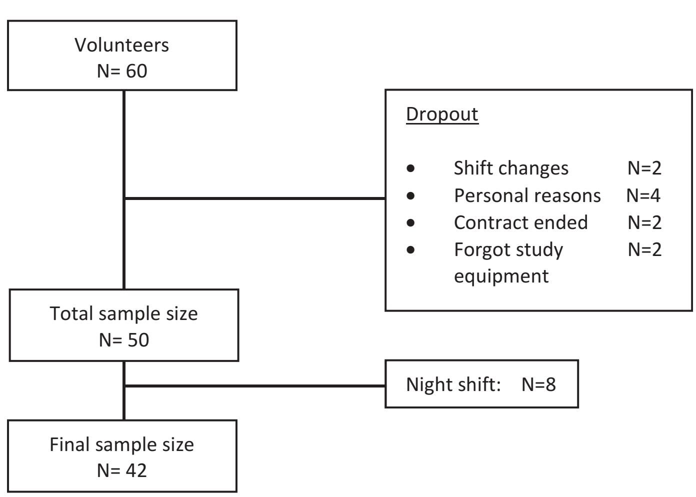

Figure 1. Flowchart.

use of actigraphy has been shown to provide acceptable accurate estimates of sleep patterns in normal, healthy adult populations (Morgenthaler et al. 2007).

An electronic version of the consensus sleep diary (CSD) was used to assess TIB, TST, SE% and SL subjectively (Carney et al. 2012). The CSD is a validated sleep diary consisting of critical core sleep parameters such as TIB, TST, SL and sleep efficiency. Responses from the CSD to these parameters were only used to confirm ambiguous actigraphy data and complement missing actigraphy data if, for instance, an event button marker was missing. On average, the CSD item scores strongly correlated with the actigraphy recordings with Pearson's $r > 0.90$. In addition, two CSD morning questions on perceived sleep quality and level of rest were used to complement the objective results on actigraphic sleep quality. The two Likert scale questions were as follows: "How would you rate the quality of your sleep?" with response options ranging from (1) very poor to (5) very good; and "How rested or refreshed did you feel when you woke up for the day?" with response options ranging from (1) not at all rested to (5) very well rested.

Sleepiness

Sleepiness was measured twice a day, in the morning and evening, with the validated Karolinska Sleepiness Scale (KSS) (Åkerstedt and Gillberg 1990). The KSS consists of a nine-point Likert scale rating sleepiness with (1) very alert, (5) neither alert nor sleepy, (9) very sleepy, fighting sleep, effort to stay awake.

Sociodemographic and explanatory variables

Sociodemographic and explanatory variables were assessed at baseline. Sociodemographic variables included gender, platform location and job demands and tenure. Explanatory variables included age, chronotype, prior offshore shift rotation sleep quality and self-reported weight and height, used to calculate body mass indices (BMI). BMI was classified into underweight (BMI <18.5), normal weight (BMI = 18.5–24.99), overweight (BMI = 25–29.99) and obesity (BMI ≥30) as per World Health Organization standards. The explanatory variable BMI was included in the models, as overweight and obesity have been shown to negatively impact sleep quality and increase sleepiness due to e.g. altered upper airway physiology (Beebe et al. 2007). Chronotype, individual differences in sleep/wake rhythm timing/diurnal preference, was assessed using the Munich Chronotype Questionnaire, and chronotype was defined as the midsleep point on days off-work corrected for sleep on working days (Roenneberg et al. 2003; Zavada et al. 2005). Chronotype was investigated as an explanatory variable as previous studies have shown that circadian preferences can explain variances in sleep quality and sleepiness among shift workers (Juda et al. 2013). Prior offshore shift sleep quality was investigated to account for inter-individual sleep quality differences and was assessed using the Pittsburgh Sleep Quality Index (PSQI) (Buysse et al. 1989). The PSQI measures self-reported sleep quality within the past month using 19 self-rated items, which are summed to a total score, ranging from 0 to 21. A score greater than 5 indicates poor sleep quality (Buysse et al. 1989).

Statistical analysis

Generalized linear and linear mixed model analyses were conducted to examine the (changes of) courses of sleep quality and sleepiness parameters in full 2on/2off offshore day shift rotation periods (pre-, offshore and post-offshore work periods). Linear mixed models were used for continuous outcome variables (TIB, TST, subjective sleep quality and level of rest) and generalized linear mixed models for categorical outcome variables (SL and SE%). The variables SL and SE% were dichotomized because of the skewed distribution and the high number of zero values. Courses of sleep quality and sleepiness parameters, during the examined offshore shift rotation periods, were investigated with the interaction term of days on shift and offshore shift rotation period (days*periods). In addition, separate analyses were performed in which shift rotation period was modelled as a categorical independent variable in all models to investigate average changes of sleep quality and sleepiness variables over the offshore shift rotation periods. Missing values were assumed to be missing at random. Under this assumption, mixed models provide valid estimates, without data imputation (Twisk et al. 2013). If extreme outliers were found, sensitivity analyses with and without the specific observations were conducted to decide on the best model.

To adjust for possible cluster effects, all investigated (generalized) linear mixed models included platform location as a fixed effect. Each platform is unique in its physical and social environment due to e.g. the remote/isolated locations of the platform, strong crew relationships and the specific technical challenges of each installation. In a univariable approach, the potential explanatory variables, age, chronotype, baseline PSQI and BMI, were added to the (generalized) linear mixed models to examine changes to the courses of sleep quality and sleepiness parameters across the investigated offshore shift periods. We defined that variables that decreased the regression coefficients of the time variables by more than 10%, after adding them to the model, could (partly) explain the observed changes over time (Table 3). All analyses were performed using SPSS version 23 (SPSS Inc., Chicago, IL).

Results

Sample characteristics

The final study sample consisted of $N = 42$ male offshore workers (Figure 1). About half of the offshore workers (48%, $N = 20$) were employed as contractors. Most offshore workers were overweight (44%, $N = 18$) or obese (15%, $N = 6$), and 76% ($N = 29$) of offshore workers were identified as poor sleepers according to the Pittsburgh Sleep Quality Index (see Table 1). Descriptive results of the sleep quality and sleepiness parameters for the investigated shift rotation periods can be found in Table 2.

Table 1. Sample characteristics of the final study sample.

	N	Mean	SD	Range
Age (years)	42	42	12.1	[21–63]
BMI	41	26.5	3.4	[21–36]
Job tenure (years)	41	6.6	6.2	[1–27]
Sleep quality past month (PSQI)	38	6.4	1.6	[4–12]
Mean mid sleep corrected (hh:mm)	38	03:01	00:37	[02:00–04:17]
	N	%		
Job demands				
Mentally demanding	14	34		
Physically demanding	5	12		
Both mentally and physically demanding	22	54		

Participants were excluded from the measure if missing values were found.
PSQI: Pittsburgh Sleep Quality Index; BMI: body mass index.

Sleep parameters

Actigraphy During the pre-offshore shift work period, the odds of having high SE% significantly decreased with a factor of 0.87 (95% CI: 0.76–0.99, p =0 .038). None of the other courses of objective sleep quality parameters significantly changed during the investigated offshore shift rotation periods (Supplement, Table 1).

Significant differences between the pre-offshore, offshore and post-offshore work periods were found for TIB ($p < 0.001$), TST ($p < 0.001$), and SE% ($p = 0.002$) (Table 3, Figure 2). TIB and TST were significantly shorter in the offshore work period compared to the pre- and post-offshore work periods. The odds of having low SE% were lowest during the offshore work period (OR = 0.63, 95% CI: 0.42–0.93, $p = 0.021$). In the offshore work periods, offshore workers had on average about a 1% higher SE% compared to pre- and post-offshore work periods. A sensitivity analysis for SE% was conducted as one participant scored very low on SE% for one sleep episode in the post-offshore work period (only 1 h of sleep). The overall outcomes for both logistic mixed model analyses, including and excluding this participant, were the same and thus the logistic mixed models including the participant were used for the final reporting (Table 3). No significant differences for SL times were found between the periods ($p = 0.427$) (Table 3). No significant changes were observed when adding potential explanatory variables to the models.

Subjective, self-reported sleep quality No significant changes to the courses of subjective, self-reported, sleep quality parameters were found within the investigated offshore shift rotation periods. A significant difference for subjective, self-reported sleep quality was found across the three offshore shift rotation periods ($p < 0.001$) (Table 3,

Table 2. Mean scores of the investigated sleep quality and sleepiness parameters for the pre-offshore (1 week), offshore (2weeks) and post-offshore (1 week) work periods.

	Pre-offshore			Offshore			Post-offshore		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
Actigraphy									
TIB (min)	495.4	77.5	293–759	453.6	63.3	250–869	502.3	105.3	51–977
TST (min)	420.1	67.5	209–684	389.3	57.9	210–857	427.4	100.8	19–912
SL (min)	10.9	16.1	0–93	11.1	17.3	0–130	9.4	15.3	0–84
SE (%)	85.1	6.9	57.6–99.5	86.1	6.7	59.6–99.8	84.8	7.8	37.3–99.7
CSD									
Sleep quality	3.5	0.8	1–5	3.3	0.8	1–5	3.5	0.8	1–5
Level of rest	3.4	0.9	1–5	3.0	0.9	1–5	3.2	0.9	1–5
KSS									
Morning	3.7	1.6	1–8	4.0	1.7	1–9	4.0	1.7	1–9
Evening	4.3	1.9	1–9	4.6	1.9	1–9	4.9	2.2	1–9

TIB: time in bed; TST: total sleep time; SL: sleep latency; SE%: sleep efficiency percentage; CSD: consensus sleep diary; KSS: Karolinska Sleepiness Scale.

Table 3. Mean differences and odds ratios of daily Karolinska Sleepiness Scores (KSS), consensus sleep diary (CSD) items and actigraphy recordings between the pre-offshore (1 week), offshore (2 weeks) and post-offshore (1 week) work periods.

	Pre-offshore			Offshore	Post-offshore		
	Mean diff	95% CI	*p* Value		Mean diff	95% CI	*p* Value
KSS							
Morning	−0.25	−0.41 to −0.08	0.004	–	−0.12	−0.31 to 0.06	0.193
Morning & Chronotype	−30	−0.48 to −0.12	0.001	–	−0.07	−0.26 to 0.12	0.479
Evening	−0.22	−0.41 to −0.04	0.020	–	0.16	−0.04 to 0.37	0.121
Evening & BMI	−0.22	−0.41 to −0.03	0.023	–	0.14	−0.06 to 0.35	0.177
Evening & PSQI	−0.17	−0.36 to 0.03	0.092	–	0.11	−0.11 to 0.32	0.326
CSD							
Sleep quality	0.18	0.08 to 0.29	0.001	–	0.26	0.14 to 0.38	<0.001
Level of Rest	0.34	0.23 to 0.45	<0.001	–	0.26	0.14 to 0.38	<0.001
Actigraphy							
TIB	42.13	31.49 to 52.76	<0.001	–	50.11	38.51 to 61.71	<0.001
TST	29.12	19.25 to 39.10	<0.001	–	40.25	29.43 to 51.07	<0.001
	OR	95% CI	*p* Value		OR	95% CI	*p* Value
SL	0.92	0.67 to 1.27	0.617	–	1.19	0.85 to 1.69	0.313
SE%	1.81	1.26 to 2.61	0.001	–	1.60	1.08 to 2.38	0.021

Offshore work period serves as reference category.
PSQI: Pittsburgh Sleep Quality Index; TIB: time in bed; TST: total sleep time; SL: sleep latency; SE%: sleep efficiency percentage.
Potential explanatory variables were added to the model if the regression coefficient of the baseline model decreased the regression coefficients of the adjusted model by at least 10%. This was the case for morning KSS (chronotype) as well as evening KSS (BMI and PSQI).

Figure 3). Perceived sleep quality was lower offshore compared to pre-offshore and post-offshore work periods. No significant differences were found between pre- and post-offshore work periods. A significant difference between level of rest after awakening was found across the three offshore shift rotation periods ($p < 0.001$) (Table 2, Figure 3). Offshore workers felt less rested after wake compared to pre- and post-offshore work periods. No significant differences were found between pre- and post-offshore work periods. No significant changes were observed when adding potential explanatory variables to the models.

Sleepiness

Significant differences for daily sleepiness scores were found during and across the three offshore shift rotation periods (Tables 2 and 3, Figure 3). Evening sleepiness courses significantly increased during the offshore work period (b = 0.06, 95% CI: 0.03–0.08, $p < 0.001$) and significantly decreased during the post-offshore work periods (b = –0.15, 95% CI: –0.25 to –.08, p = 0.004). No significant differences in the courses of morning sleepiness scores across the three offshore shift rotation periods were found.

When investigating effects across the offshore shift rotation periods, morning sleepiness scores

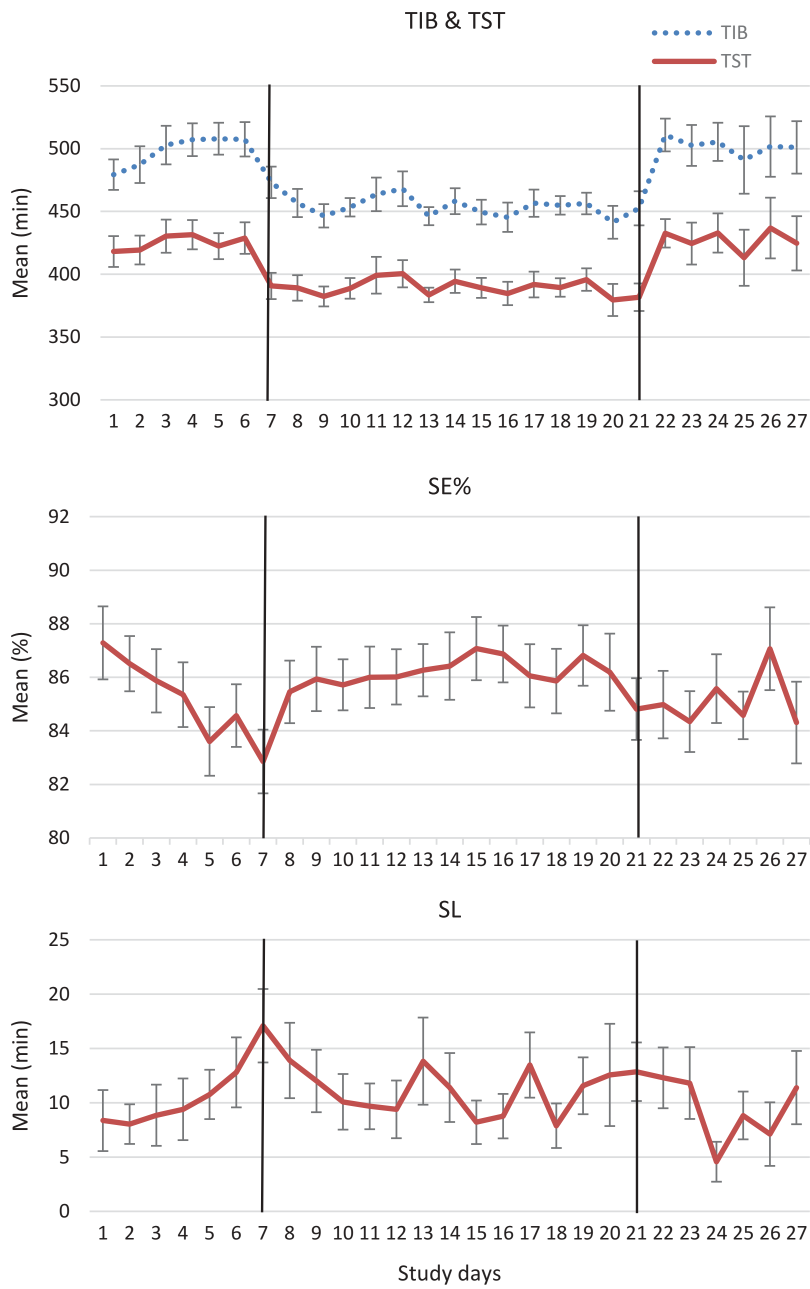

Figure 2. Courses of objective TIB, TST, SE% and SL actigraphy recordings across full 2 weeks on/2 weeks off offshore shift rotations.

differed significantly between pre-, offshore and post-offshore work periods (p = 0.015). The highest morning sleepiness levels were found during the offshore work period compared to the pre- and post-offshore work periods. Evening sleepiness differed significantly across the offshore shift rotation periods (p = 0.005). The highest evening sleepiness levels were found in the post-offshore work period followed by the offshore work period and the pre-offshore work period. Out of the four investigated potential explanatory variables, BMI, chronotype, and prior offshore shift rotation sleep quality (baseline PSQI) may explain the differences in sleepiness parameters, as they decreased the regression coefficients of the time parameters.

Discussion

Sleep quality and sleepiness parameters significantly differed across full 2on/2off offshore day shift rotation periods. Significant changes in the courses of SE% and evening sleepiness scores were

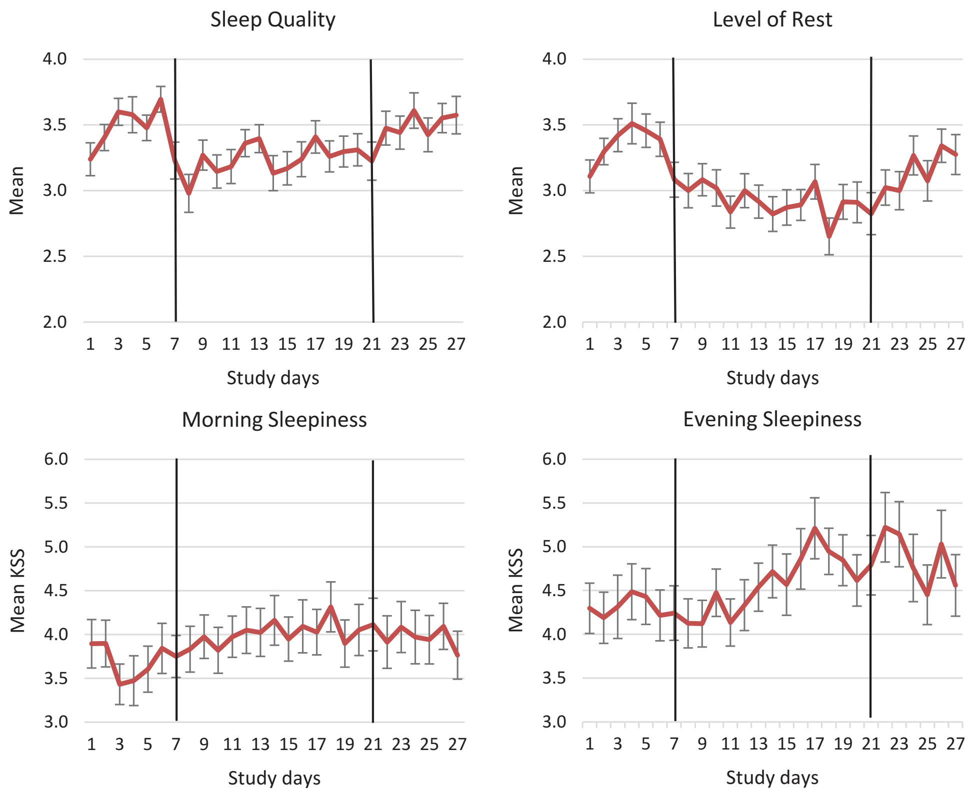

Figure 3. Courses of self-reported sleep quality, level of rest and sleepiness across 2 weeks on/2 weeks off offshore shift rotations.

found. In the pre-offshore work period, SE% scores significantly decreased. The courses of evening sleepiness scores significantly increased during offshore work periods and significantly decreased in the post-offshore work periods. In addition, during offshore work periods, TIB and TST were significantly shorter; SE% was significantly higher and morning sleepiness scores were significantly higher compared to pre- and post-offshore work periods. Average evening sleepiness scores were significantly higher in the post-offshore work period compared to the pre- and offshore work periods.

The courses of SE% and evening KSS significantly differed across the offshore shift rotation periods. During the pre-offshore work period, the courses of SE% scores significantly decreased, rejecting the first part of our first hypothesis that sleep quality would decrease during the offshore work period. Although not significant, TIB, TST and SL times increased in the pre-offshore shift rotation period as well. Together, these findings could reflect a potential pre-offshore work "preparation" phase, in which offshore workers enjoy the comforts of the home sleep environment and try to bank sleep (i.e. building up a sleep credit by sleeping extra hours prior to offshore shifts). However, given that SE% courses significantly decreased in the pre-offshore work period, we can assume that this sleep banking is not efficient as not enough time is spent asleep based on the time spent in bed. The courses of evening sleepiness scores significantly increased during the offshore shift rotation period and significantly decreased during the post-offshore work period, confirming the second part of our first hypothesis that sleepiness levels will increase during the offshore work periods and decrease in the post-offshore work periods. This finding is also in line with previous results on increased sleepiness risk during offshore work periods (Waage et al. 2012) and sleepiness recovery during leave periods (Wadsworth et al. 2006).

During the offshore work period, offshore workers slept between 45 min and 50 min less compared to pre- and post-offshore work periods confirming the first part of our second hypothesis that sleep durations are shorter during offshore work periods. This finding is in line with a study among Australian mining workers, showing that total sleep time while onsite for 2 weeks was significantly shorter for both day and night shifts compared to the leave periods (Ferguson et al. 2010). Although the sleep durations of the offshore workers were within recommended guidelines of 7–9 h of sleep per night (Hirshkowitz et al. 2015), their sleep durations were significantly shorter during the offshore work period compared to their pre- and post-offshore work periods. This finding is also in line with previous findings from Saksvik et al. (2011), who showed that sleep durations were longer in the week preceding the offshore work period. This divergence between sleep durations during leave periods and cumulated shorter sleep durations during work periods can have substantial adverse health and safety effects. It has been shown that the loss of as little as 1 h of sleep per night results in progressive increase in daytime sleepiness (Åkerstedt 1991; Carskadon and Dement 1981). Moreover, a study among Chinese seafarers found that if the actual amount of sleep per night was lower compared to Chinese seafarers' ideal amount of sleep, their experienced sleep quality was lower and their tiredness level and distress increased (Zhao et al. 2016). Our finding corresponds with the results of the Chinese seafarer study, as TIB was shorter in offshore work periods together with lower subjective, self-reported sleep quality levels, levels of rest and increased sleepiness scores.

SE% significantly increased by roughly 1% during the offshore work period while SL did not significantly change across the offshore shift rotation period; therewith rejecting the second part of our second hypothesis, that SE% will be lower and SL times will be shorter during offshore work periods. Although a 1% increase in SE% was statistically significant, it is a very small difference. Overall, offshore workers had SE% scores higher than 85%, indicating that SE% was good for all offshore shift rotation periods. Research has shown that only if SE% is below 80%, health is negatively impacted (Dew et al. 2003). Regarding SL, some previous studies have criticized the scoring of SL with actigraphy as actigraph algorithms tend to overscore sleep periods for sleep latencies (Chae et al. 2009; Lichstein et al. 2006). Thus, actigraphy might not provide accurate estimates of SL and explain the non-significant findings of SL between the investigated offshore periods.

Morning sleepiness scores were highest during the offshore work period compared to pre- and post-offshore work periods, confirming our third hypothesis that sleepiness levels are high during the offshore work period. Although average sleepiness scores were rather low, the increase in sleepiness during offshore work should not be neglected. As for some offshore workers, this small difference might be of relevance. In previous research, sleepiness has been directly linked with workplace health and safety outcomes. For example, prolonged sleepiness, because of inadequate sleep opportunity and recovery, has been shown to decrease work performance and to lead to more incidents (Niu et al. 2011). Moreover, usually KSS items follow a stable diurnal U-shaped rhythm with higher KSS scores in the morning and late afternoon (Åkerstedt et al. 2014). We found, on average, higher sleepiness levels in the evening compared to the morning. Morning sleepiness scores were similar to day average sleepiness scores of a previously conducted offshore study, whereas evening sleepiness scores were higher, upon visual inspection of Figure 2 in Waage et al. (2012; p. 69). Unfortunately, the authors' only report averaged day values for sleepiness and therefore no direct comparison was possible. Furthermore, evening sleepiness scores were significantly higher in the post-offshore work periods compared to the pre- and offshore work periods with evening sleepiness scores approaching levels similar to those of offshore night shift workers (Merkus et al. 2015a). This finding stresses the magnitude of potential sleep and sleepiness problems in the investigated offshore population. While morning KSS scores returned relatively quickly to their normal states, evening KSS scores increased and remained high in the post-offshore work period. The significant higher evening KSS scores in the post-offshore work period may be indicative of a post-offshore work recovery period and confirms our fourth hypothesis of high sleepiness scores in the post-offshore work period.

Previous studies on offshore day and night shift workers have found that there is a 'recovery period' upon returning to the home environment after an offshore shift, which can last up to 14 days (Merkus et al. 2015b; Riethmeister et al. 2016; Thorne et al. 2010; Waage et al. 2012). These studies illustrate the complexity of readaptation to day life after working offshore shifts. Notably, the readaptation challenges following offshore work were more pronounced among night shift workers compared to day shift workers. It may take several days in the home environment before all sleepiness states, especially evening sleepiness scores, return to baseline (pre-offshore work) levels, even though sleep durations (time in bed) are immediately extended in the post-offshore work period. These long recovery periods after 2-week offshore shifts and their potential negative effect on offshore workers' personal health, safety and social interactions have been previously reported (Merkus et al. 2015b). Road safety is one of these occupational concerns. Long recovery periods and embarking on (long) commutes after offshore shifts can potentially increase the risks of being involved in a road accident (Rogers et al. 2001). These results should be considered in offshore health, safety and particularly fatigue, risk management programmes to improve offshore workers' health, safety and performances.

Strengths and limitations

A strength of this longitudinal, repeated measurement study is the analyses of sleep quality and sleepiness courses in full 2on/2off offshore shift rotation settings and the differentiation between pre-offshore, offshore and post-offshore work periods. Moreover, continuous daily objective and subjective, self-reported measures were used to examine changes in the courses of sleep quality and sleepiness in full 2on/2off offshore shift rotation periods. Additionally, four potential explanatory variables of the changes in the course of sleep quality and sleepiness parameters across full 2on/2off offshore shift rotations were investigated.

Limitations mainly concern operational (e.g. work scheduling) and material constraints (e.g. intrinsic safety obligations of study measures) and their impacts on the study design. The sample was rather small (N = 42); however, the repeated measures allowed us to examine the courses of sleep quality and sleepiness in full 2on/2off offshore day shift rotations. Due to the small sample size, we had to prioritize which potential explanatory variables to investigate and prohibited us to explore other potential explanatory variables such as health status and work characteristics. Furthermore, due to the study set-up, an objective sleepiness test like the multiple sleep latency test (MSLT) (Carskadon et al. 1986) to assess daily variations in objective sleepiness scores could not be conducted. However, the KSS has been found to be as sensitive and valid as the MSLT to assess sleepiness in individuals and the KSS is particularly suited for field research (Åkerstedt et al. 2014).

Moreover, multiple KSS assessments during the day would have been preferred; however, the extensive time investment of going back and forth between the work and accommodation block prevented these multiple assessments. Due to privacy and data ownership rights, it was not possible to accurately estimate the catchment area as flight data are owned by an independent secondary company. In addition, we do not have data on any night shift performed in the previous offshore tour. Although all participating offshore workers had at least 1 week of recovery period at home before the study start, we are not aware of any impact of previous shift rosters on the offshore workers. The study should be replicated in other offshore environments and various offshore shift lengths to confirm the results.

Implications

Findings on the magnitude of potential sleep and sleepiness problems in the investigated offshore day shift population should be communicated to offshore workforces and their managers. Our results show that offshore day shift workers, just as offshore night and swing shift workers, experience sleep and sleepiness problems during offshore shift rotations. To create awareness about sleep and sleepiness problems, offshore employees and their employers should be educated about the findings and potential implications of this study. As an example, the increased sleepiness risk over the course of offshore shifts could be considered in (work tasks and roster) scheduling activities to improve and warrant health, safety and productivity of employees. Additionally, actively promoting pre-offshore work *preparation* activities, such as e.g. sleep banking, could potentially counteract the negative effects of sleep debts such as increased sleepiness levels due to e.g. long commutes (Axelsson and Vyazovskiy 2015). Moreover, managed worksite napping and/or caffeine intake strategies might balance out the experienced evening sleepiness dip and the accumulated sleep debts during offshore work periods (Hartzler 2014; Horne et al. 2008). These intervention strategies might be used to improve fatigue risk mitigation strategies for offshore workers. More rigorous research is needed to evaluate the effectiveness of these intervention strategies.

In addition, evening sleepiness measures may be a sensitive measure for cumulative occupational fatigue among (offshore) day shift workers and could be used in shift work fatigue prediction models. These potential fatigue prediction models, shift roster considerations and intervention strategies do not only apply to the offshore work sector, but could potentially be generalized to similar shift work environments in which remote work and extended work hours are being operated.

Future research

More research is needed to investigate the effects of various offshore shift rotations on sleep quality and sleepiness levels to make informed decisions about optimal offshore shift durations. To date, only a few studies and industry reports have tried to compare and give advice about optimal offshore shift durations; however, results are inconclusive. Investigation and advice on optimal shift lengths would also benefit other comparable shift work sectors, in which employees work a consecutive number of days. Furthermore, more research should consider the potential health and safety implications of whole (offshore) shift rotations. Both our findings and findings of previous studies have shown that the pre- and post-work periods are important to consider for occupational health and safety management. For the investigated offshore workforce, particularly the post-offshore work period holds several unaddressed and unmanaged risks, which could be improved with appropriate fatigue risk mitigation strategies. Finally, future research should examine the differences between objective and subjective sleep quality and sleepiness findings in more detail.

Conclusions

Results from this study showed differences in the courses of sleep quality and sleepiness scores across full 2on/2off offshore shift rotations. In the pre-offshore work period, SE% scores significantly decreased whereas during offshore work periods the courses of evening sleepiness scores significantly increased and significantly decreased again during post-offshore work periods. Moreover, in the offshore work period, offshore workers slept less, their perceived sleep quality and level of rest after awakening decreased, and morning sleepiness scores increased. In contrast, their objective sleep efficiency remained good and no differences in sleep latencies were observed. Interestingly, evening sleepiness scores were highest in post-offshore work period, indicative of a post-offshore work recovery period. The identified courses of sleep quality and sleepiness scores should be considered in offshore health, safety and particularly fatigue, risk management programmes to improve health, safety and performance of offshore workers.

Acknowledgements

We would like to thank all offshore workers participating in this study for their contribution. In addition, we would like to acknowledge the logistic and technical help of Mireille Folkerts in the set-up and conduction of the study.

Declaration of Interest

This research was supported and funded by the Nederlandse Aardolie Maatschappij B.V. and Royal Dutch Shell, Assen, Drenthe, The Netherlands. Vanessa Riethmeister works full time as an insights analyst at the Health, Safety and Environment Department at Royal Dutch Shell. In addition, she is an external PhD student at the Department of Health Sciences, Community and Occupational Medicine, University Medical Center Groningen, University of Groningen, The Netherlands. The authors report no conflicts of interest.

References

Åkerstedt T. 1991. Human performance and cognition. Sleep, sleepiness and performance. Sleepiness at work: Effects of irregular work hours. In Monk TH, editor. Oxford, England: John Wiley & Sons. p. 129–52.

Åkerstedt T, Anund A, Axelsson J, Kecklund G. 2014. Subjective sleepiness is a sensitive indicator of insufficient sleep and impaired waking function. J Sleep Res. 23 (3):240–52. doi:10.1111/jsr.12158.

Åkerstedt T, Gillberg M. 1990. Subjective and objective sleepiness in the active individual. Int J Neurosci. 52(1–2):29–37. doi:10.3109/00207459008994241.

Åkerstedt T, Philip P, Capelli A, Kecklund G. 2011. Sleep loss and accidents-work hours, life style, and sleep pathology. Hum Sleep Cognition, Pt II: Clin Appl Res. 190:169–88. doi:10.1016/B978-0-444-53817-8.00011-6.

Arlinghaus A, Lombardi DA, Willetts JL, Folkard S, Christiani DC. 2012. A structural equation modeling approach to fatigue-related risk factors for occupational injury. Am J Epidemiol. 176(7):597–607. doi:10.1093/aje/kws219.

Axelsson J, Vyazovskiy VV. 2015. Banking sleep and biological sleep need. Sleep. 38(12):1843–45. doi:10.5665/sleep.5222.

Beebe DW, Lewin D, Zeller M, McCabe M, MacLeod K, Daniels SR, Amin R. 2007. Sleep in overweight adolescents: Shorter sleep, poorer sleep quality, sleepiness, and sleep-disordered breathing. J Pediatr Psychol. 32(1):69–79. doi:10.1093/jpepsy/jsj104.

Bjorvatn B, Kecklund G, Åkerstedt T. 1999. Bright light treatment used for adaptation to night work and re-adaptation back to day life. A field study at an oil platform in the North Sea. J Sleep Res. 8(2):105–12. doi:10.1046/j.1365-2869.1999.00146.x.

Buysse DJ, Reynolds CF, Monk TH, Berman SR, Kupfer DJ. 1989. The Pittsburgh Sleep Quality Index - A new instrument for psychiatric practice and research. Psychiatry Res. 28(2):193–213. doi:10.1016/0165-1781(89)90047-4.

Carney CE, Buysse DJ, Ancoli-Israel S, Edinger JD, Krystal AD, Lichstein KL, Morin CM. 2012. The consensus sleep diary: Standardizing prospective sleep self-monitoring. Sleep. 35(2):287–302. doi:10.5665/sleep.1642.

Carskadon MA, Dement WC. 1981. Cumulative effects of sleep restriction on daytime sleepiness. Psychophysiology. 18(2):107–13. doi:10.1111/j.1469-8986.1981.tb02921.x.

Carskadon MA, Dement WC, Mitler M, Roth T, Westbrook P, Keenan S. 1986. Guidelines for the multiple sleep latency test (MSLT) - A standard measure of sleepiness. Sleep. 9(4):519–24. PMID:3809866.

Chae KY, Kripke DF, Poceta JS, Shadan F, Jamil SM, Cronin JW, Kline LE. 2009. Evaluation of immobility time for sleep latency in actigraphy. Sleep Med. 10(6):621–25. doi:10.1016/j.sleep.2008.07.009.

Dew M, Hoch C, Buysse D, Monk T, Begley A, Houck P, Hall M, Kupfer D, Reynolds C. 2003. Healthy older adults' sleep predicts all-cause mortality at 4 to 19 years of follow-up. Psychosom Med. 65(1):63–73. doi:10.1097/01.PSY.0000039756.23250.7C.

Elbaz M, Yauy K, Metlaine A, Martoni M, Leger D. 2012. Validation of a new actigraph motion watch versus polysomnography on 70 healthy and suspected sleep-disordered subjects. J Sleep Res. 21:218.

Ferguson SA, Baker AA, Lamond N, Kennaway DJ, Dawson D. 2010. Sleep in a live-in mining operation: The influence of start times and restricted non-work activities. Appl Ergon. 42(1):71–75. doi:10.1016/j.apergo.2010.05.001.

Folkard S, Tucker P. 2003. Shift work, safety and productivity. Occupational Medicine-Oxford. 53(2):95–101. doi:10.1093/occmed/kqg047.

Gehrman P, Matt G, Turingan M, Dinh Q, Ancoli-Israel S. 2002. Towards an understanding of self-reports of sleep. J Sleep Res. 11(3):229–36. doi:10.1046/j.1365-2869.2002.00306.x.

Geurts SAE, Sonnentag S. 2006. Recovery as an explanatory mechanism in the relation between acute stress reactions and chronic health impairment. Scand J Work Environ Health. 32(6):482–92. doi:10.5271/sjweh.1053.

Gibbs M, Hampton S, Morgan L, Arendt J. 2002. Adaptation of the circadian rhythm of 6-sulphatoxymelatonin to a shift schedule of seven nights followed by seven days in offshore oil installation workers. Neurosci Lett. 325(2):91–94. doi:10.1016/S0304-3940(02)00247-1.

Gibbs M, Hampton S, Morgan L, Arendt J. 2007. Predicting circadian response to abrupt phase shift: 6-sulphatoxymelatonin rhythms in rotating shift workers offshore. J Biol Rhythms. 22(4):368–70. doi:10.1177/0748730407302843.

Gordon RPE. 1998. The contribution of human factors to accidents in the offshore oil industry. Reliab Eng Syst Saf. 61(1–2):95–108. doi:10.1016/S0951-8320(98)80003-3.

Harris A, Waage S, Ursin H, Hansen AM, Bjorvatn B, Eriksen HR. 2010. Cortisol, reaction time test and health among offshore shift workers. Psychoneuroendocrinology. 35(9):1339–47. doi:10.1016/j.psyneuen.2010.03.006.

Hartzler BM. 2014. Fatigue on the flight deck: The consequences of sleep loss and the benefits of napping. Accid Anal Prev. 62:309–18. doi:10.1016/j.aap.2013.10.010.

Hirshkowitz M, Whiton K, Albert SM, Alessi C, Bruni O, DonCarlos L, Hazen N, Herman J, Adams Hillard PJ, Katz ES, et al 2015. National sleep foundation's updated sleep duration recommendations: Final report. Sleep Health: J Natl Sleep Found. 1(4):233–43. doi:10.1016/j.sleh.2015.10.004.

Horne J, Anderson C, Platten C. 2008. Sleep extension versus nap or coffee, within the context of 'sleep debt'. J Sleep Res. 17(4):432–36. doi:10.1111/j.1365-2869.2008.00680.x.

Jansen NWH, Kant I, van Amelsvoort LGPM, Nijhuis FJN, van den Brandt P. 2003. Need for recovery from work: Evaluating short-term effects of working hours, patterns and schedules. Ergonomics. 46(7):664–80. doi:10.1080/0014013031000085662.

Jepsen JR, Zhao Z, Van Leeuwen WM. 2015. Seafarer fatigue: A review of risk factors, consequences for seafarers' health and safety and options for mitigation. Int Marit Health. 66 (2):106–17. doi:10.5603/IMH.2015.0024.

Juda M, Vetter C, Roenneberg T. 2013. Chronotype modulates sleep duration, sleep quality, and social jet lag in shift-workers. J Biol Rhythms. 28(2):141–51. doi:10.1177/0748730412475042.

Kecklund G, Ekstedt M, Åkerstedt T, Dahlgren A, Samuelson B. 2001. The effects of double-shifts (15.5 hours) on sleep, fatigue and health. J Hum Ergol. 30(1–2):53–58. PMID:14564858.

Kim R, van den Berg M. 2010. Summary of night noise guidelines for Europe. Noise Health. 12(47):61–63. doi:10.4103/1463-1741.63204.

Kivimaeki M, Batty GD, Hamer M, Ferrie JE, Vahtera J, Virtanen M, Marmot MG, Singh-Manoux A, Shipley MJ. 2011. Using additional information on working hours to predict coronary heart disease. Ann Intern Med. 154 (7):457. doi:10.7326/0003-4819-154-7-201104050-00003.

Lichstein KL, Stone KC, Donaldson J, Nau SD, Soeffing JP, Murray D, Lester KW, Aguillard N. 2006. Actigraphy validation with insomnia. Sleep. 29(2):232–39. PMID:16494091.

Menezes M, Pires M, Benedito-Silva A, Tufik S. 2004. Sleep parameters among offshore workers: An initial assessment in the Campos Basin, Rio De Janeiro, Brazil. Chronobiol Int. 21(6):889–97. doi:10.1081/LCBI-200036876.

Merkus SL, Holte KA, Huysmans MA, Hansen AM, van de Ven PM, van Mechelen W, van der Beek AJ. 2015b. Neuroendocrine recovery after 2-week 12-h day and night shifts: An 11-day follow-up. Int Arch Occup Environ Health. 88(2):247–57. doi:10.1007/s00420-014-0954-5ER.

Merkus SL, Holte KA, Huysmans MA, van de Ven PM, van Mechelen W, van der Beek AJ. 2015a. Self-reported recovery from 2-week 12-hour shift work schedules: A 14-day follow-up. Saf Health Work. 6(3):240–48. doi:10.1016/j.shaw.2015.07.003.

Morgenthaler T, Alessi C, Friedman L, Owens J, Kapur V, Boehlecke B, Brown T, Chesson A Jr., Coleman J, Lee-Chiong T, et al 2007. Practice parameters for the use of actigraphy in the assessment of sleep and sleep disorders: An update for 2007. Sleep. 30(4):519–29. PMID:17520797. doi:10.1093/sleep/30.4.519.

Muller R, Carter A, Williamson A. 2008. Epidemiological diagnosis of occupational fatigue in a fly-in-fly-out operation of the mineral industry. Ann Occup Hyg. 52(1):63–72. doi:10.1093/annhyg/mem058.

Mullins HM, Cortina JM, Drake CL, Dalal RS. 2014. Sleepiness at work: A review and framework of how the physiology of sleepiness impacts the workplace. J Appl Psychol. 99(6):1096–112. doi:10.1037/a0037885.

National Sleep Foundation. 2018. [accessed 2018, Feb 1]. https://sleep.org/.

Niu S, Chung M, Chen C, Hegney D, O'Brien A, Chou K. 2011. The effect of shift rotation on employee cortisol profile, sleep quality, fatigue, and attention level: A systematic review. J Nurs Res. 19(1):68–81. doi:10.1097/JNR.0b013e31820c1879.

Parkes K. 1994. Sleep patterns, shiftwork, and individual-differences - A comparison of onshore and offshore control-room operators. Ergonomics. 37(5):827–44. doi:10.1080/00140139408963692.

Parkes KR. 1993. Human factors, shift work and alertness in the offshore oil industry. Part I A survey of onshore and offshore control room operators. Part II alertness, sleep and cognitive performance. London: HMSO. Report nr OTH 92-389.

Parkes KR. 2002. Age, smoking, and negative affectivity as predictors of sleep patterns among shiftworkers in two environments. J Occup Health Psychol. 7(2):156–73. doi:10.1037//1076-8998.7.2.156.

Parkes KR. 2012. Shift schedules on North Sea oil/gas installations: A systematic review of their impact on performance, safety and health. Saf Sci. 50(7):1636–51. doi:10.1016/j.ssci.2012.01.010.

Parkes KR. 2015. Sleep patterns of offshore day-workers in relation to overtime work and age. Appl Ergon. 48:232–39. doi:10.1016/j.apergo.2014.12.004.

Parkes KR. 2016. Age and work environment characteristics in relation to sleep: Additive, interactive and curvilinear effects. Appl Ergon. 54:41–50. doi:10.1016/j.apergo.2015.11.009.

Portaluppi F, Smolensky MH, Touitou Y. 2010. Ethics and methods for biological rhythm research on animals and human beings. Chronobiol Int. 27(9–10):1911–29. doi:10.3109/07420528.2010.516381.

Riethmeister V, Brouwer S, van der Klink J, Bültmann U. 2016. Work, eat and sleep: Towards a healthy ageing at work program offshore. BMC Public Health. 16:134. doi:10.1186/s12889-016-2807-5.

Roenneberg T, Wirz-Justice A, Merrow M. 2003. Life between clocks: Daily temporal patterns of human chronotypes. J Biol Rhythms. 18(1):80–90. doi:10.1177/0748730402239679.

Rogers A, Holmes S, Spencer M. 2001. The effect of shiftwork on driving to and from work. J Hum Ergol. 30(1–2):131–36. doi:10.11183/jhe1972.30.131.

Saksvik IB, Bjorvatn B, Harvey AG, Waage S, Harris A, Pallesen S. 2011. Adaptation and readaptation to different shift work schedules measured with sleep diary and actigraphy. J Occup Health Psychol. 16(3):331–44. doi:10.1037/a0022770.

Thorne HC, Hampton SM, Morgan LM, Skene DJ, Arendt J. 2010. Returning from night shift to day life: Beneficial effects of light on sleep. Sleep Biol Rhythms. 8(3):212–21. doi:10.1111/j.1479-8425.2010.00451.x.

Twisk J, de Boer M, de Vente W, Heymans M. 2013. Multiple imputation of missing values was not necessary before performing a longitudinal mixed-model analysis. J Clin Epidemiol. 66(9):1022–28. doi:10.1016/j.jclinepi.2013.03.017.

U.S. Chemical Safety and Hazard Investigation Board. 2016. Investigation report volume 3 drilling rig explosion and fire at the Macondo well. Report nr 2010-10-I-OS.

Uehli K, Mehta AJ, Miedinger D, Hug K, Schindler C, Holsboer-Trachsler E, Leuppi JD, Kuenzli N. 2014. Sleep problems and work injuries: A systematic review and meta-analysis. Sleep Med Rev. 18(1):61–73. doi:10.1016/j.smrv.2013.01.004.

Waage S, Harris A, Pallesen S, Saksvik IB, Moen BE, Bjorvatn B. 2012. Subjective and objective sleepiness among oil rig workers during three different shift schedules. Sleep Med. 13(1):64–72. doi:10.1016/j.sleep.2011.04.009.

Waage S, Pallesen S, Moen BE, Bjorvatn B. 2013. Sleep and health in oil rig workers-before and after a two week work period offshore. Ind Health. 51(2):172–79. PMID:23196391. doi:10.2486/indhealth.2012-0091.

Wadsworth EJK, Allen PH, Wellens BT, McNamara RL, Smith AP. 2006. Patterns of fatigue among seafarers during a tour of duty. Am J Ind Med. 49(10):836–44. doi:10.1002/aijn.20381.

Zavada A, Gordijn MCM, Beersma DGM, Daan S, Roenneberg T. 2005. Comparison of the Munich Chronotype Questionnaire with the Horne-Ostberg's morningness-eveningness score. Chronobiol Int. 22(2):267–78. doi:10.1081/CBI-200053536.

Zhao Z, Jepsen JR, Chen Z, Wang H. 2016. Experiences of fatigue at sea - A comparative study in European and Chinese shipping industry. J Biosci Med. 4:65–68. doi:10.4236/jbm.2016.43011.